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Water Cooled Ultra Low Freezer Performance and Energy Use

Dometic Model UP 755 G

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Product Website: http://bakerco.com/freezers-UF.pdf

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Disclaimer

Acknowledgments

UC Davis acknowledges the support provided by the manufacturers of this equipment who loaned, shipped and advised us on correct operation and testing methods.

UC Davis recognizes the commitment of the participating establishments to increasing the energy efficiency of their facilities and eagerness to support conservation initiatives. The enthusiasm of the facility staff to accommodate our on-site visits and needs was appreciated.

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UC Davis Students played an integral role in collecting data sets, moving and unpacking freezers, assembling and calibrating thermocouples. Any errors in reporting are not to be attributed to their work as it was reviewed and supervised by career staff.

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Gratitude

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Introduction

The energy intensity of laboratories has come into focus over recent years, and Labs21 has provided a website to publish this data. As well, building designers are looking for new ways to reduce building plug load and cooling from reject heat. The energy consumption of water cooled freezers is lower than air cooled units, and reject heat is shed into process cooling loops.

During September, 2011 staff and students from the office of Environmental Stewardship and Sustainability tested three water cooled, ultra low freezers (ULF, Tables 1 and 2). The manufacturers kindly shipped, helped install the freezers and advised this project. Without their enthusiastic participation it could not have occurred and we are very grateful. The results from the Dometic freezer testing are presented here.

Distributor	**Baker**
Manufacturer	**Dometic**
Model	UP 755 G
Face Width (")	36
Door Swing Min. (")	2
Cubic Feet	26.6
2" Boxes	500
Boxes/Linear Foot	158

Table 1. Ultra Low Freezer dimensions and capacities.

Distributor	**Baker**
Manufacturer	**Dometic**
Heat Exchangers	1
Water flow (lpm)	14
Water Delta T (°C)	1
Outer Door Hinge	Pivot; Autoclose
Door Swing	100°
Outer Door	3" SIP
Latch	Easy snap, passive with a push
Gaskets	3 closed, on door
Inner Doors	Insulated, narrow handle
Vacuum Relief	Rear
	heated
Noise	62 dBA

Table 2. Freezer Construction and Doors. Water flow was measured when compressors were on. The Dometic freezer has vacuum sealed walls that are thin and allow a lighter design overall, and the door stops at 90 degrees.

Testing methods

Energy

We used Elite Pro energy meters on loan to UC Davis from the Pacific Gas and Electric Tool Lending Library, set up with 15 Amp current transducers (CT's). Split cord pigtails provided single conductors for CT placement, or CT's were placed over single conductors inside the mechanical cabinet. All three freezer amperages were measured simultaneously to obtain Volt-Amp values. Power factor was measured individually on each freezer by attaching voltage clips in a bare wire outlet box before energizing and then insulated, thus avoiding live connection hazards. We multiplied Volt-Amps by the power factors to calculate Watts during subsequent tests. Freezers were allowed to stabilize at each temperature for 6 –10 hours, then energy measurements were logged either at 1 minute or 5 minute intervals and averaged over at least 8 hours. Freezers were empty during all tests.

Temperature

On the recommendation of cryo-temperature experts in the UC Davis Physics Department, we selected type J thermocouple (TC) wire for temperature sensing. We cut and welded 13 TC's at either 3 or 5 meters, and attached them to type J plugs. They were inter-calibrated for precision in a methanol bath with dry ice chunks and stirring. Three TC's were measured during both calibration sessions and averaged. Offsets from these averages were calculated for each TC and were applied to temperature readings, (Appendix B).

Up to eight TC's were logged simultaneously using an Omega TC-08 panel. Two TC's were placed in each ULF, one next to the installed temperature probe, and one in the geometric center of the cabinet, about 4 cm above the shelf. Intake air temperature was logged on the grill. Occasional room temperature measurements were made with an infrared thermometer, and room temperature was 21.4 +- 0.3 C.

Results

Temperature Characteristics

The purpose of this test was not detailed assessment of spatial and temporal uniformity. Some data was collected from the two TC's in the middle of the freezer and next to the sensor, (Table 3). The middle of the freezer was generally colder that at the sensors, which generally was near the bottom of the freezer. Further testing of temperature characteristics will be performed on loaded and unloaded air cooled freezers.

	Dometic
Mean	-79.6
Max-Min	0.8
Measured - Set Point	0.4
Sensor - Middle	-0.5

Table 3. Temperature values over time and uniformity in the cabinet, (set point -80 degrees). Complete data available at -60 - -86°C in the appendix.

Energy Consumption

The Dometic ULF consumed about 15 kWh/d at minus eighty Celsius, (Table 4). The energy intensity per box and cubic foot were calculated as well.

	Dometic
Energy Use kWh/d	15.1
Power Factor	0.86
Energy Intensity (W/CF)	23.7
Energy Intensity (W/Box)	1.26
Electricity Cost/y (8.5 c/kWh)	$ 468
Electricity Cost/Box/y	$ 0.94

Table 4. Energy consumption and intensity at the set point -80 °C.

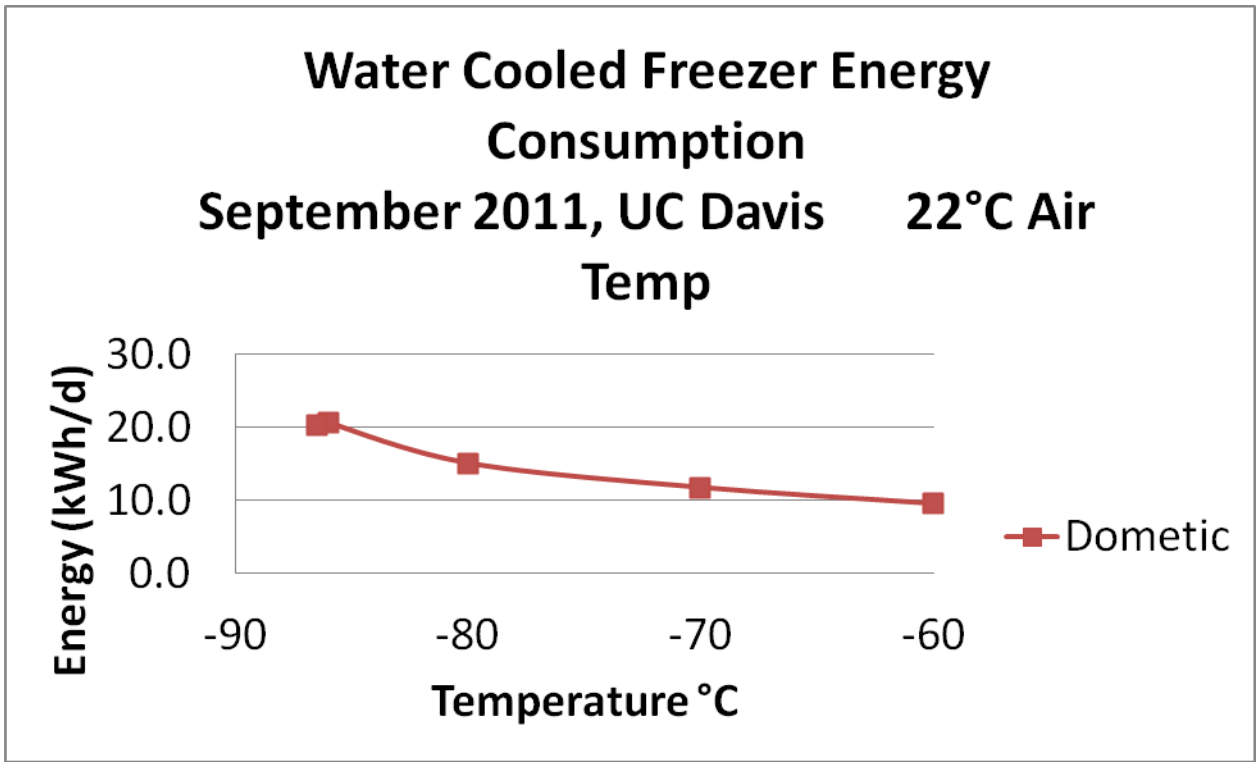


Figure 1. Energy consumption of Dometic ultra low, water cooled freezer at four set points. Second point at -86 °C is with cooling water reduced from 14 lpm to 4 lpm.

Water Consumption

The intended coolant for these freezers is re-circulated district chilled water or water from a cooling tower, so water flow is not a major energy consideration under normal circumstances. The markedly lower ($1/10^{th}$). This could be a factor in emergency situations where process cooling pumping may be compromised. The very low Delta T and the lack of any difference in energy consumption when water flow was reduced by 75% indicates the Dometic freezer needs additional commissioning before installation.

Appendices.

A) Complete temperature measurements and deviations.

Mean Temperature measured at Sensor

	Dometic
-60	-60.2
-70	-69.7
-80	-79.6
-86	-85.4

Mean Temperature measured in middle of freezer

	Dometic
-60	-63.4
-70	-71.1
-80	-79.1
-86	-84.1

Sensor °C - Middle °C

	Dometic
-60	3.3
-70	1.4
-80	-0.5
-86	-1.2

Temperature uniformity got better as set point decreased, a surprising result.

Temporal Range (Max-Min)

	Dometic
-60	1.0
-70	1.3
-80	0.8
-86	0.5

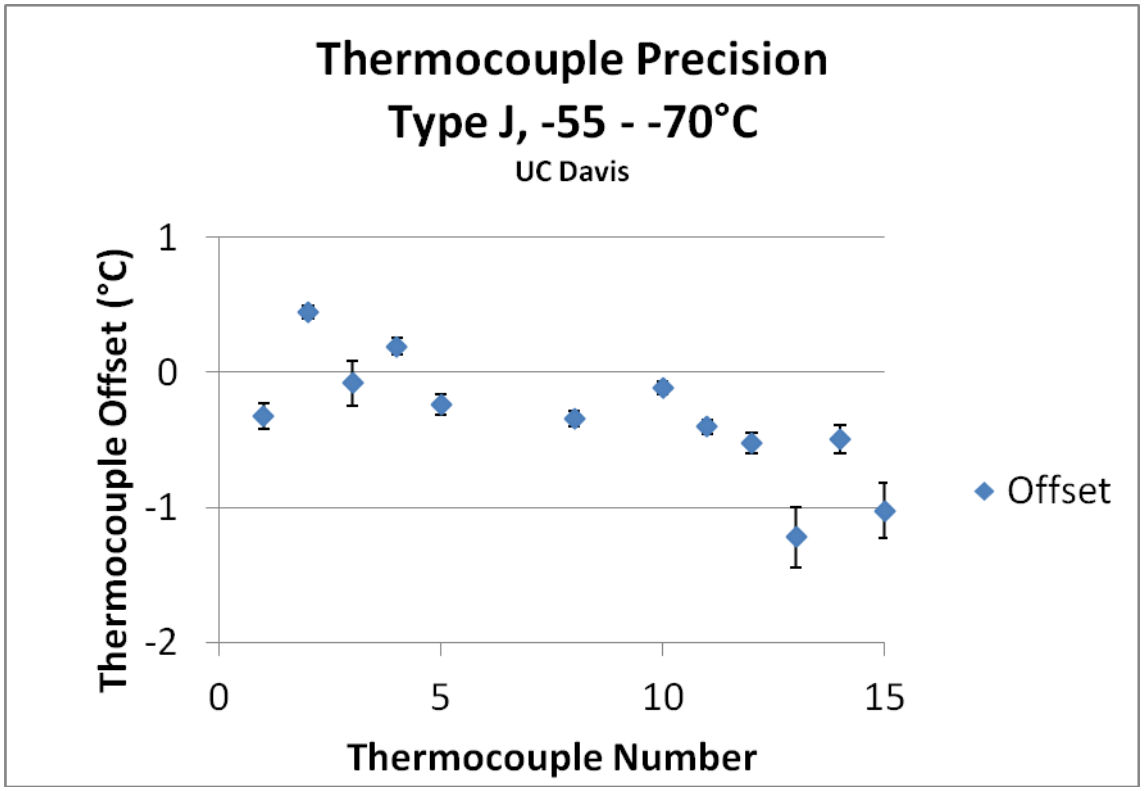
Temporal uniformity was about 1 degree Celsius over the duty cycle in an empty freezer.

Sensor °C -Set Pt

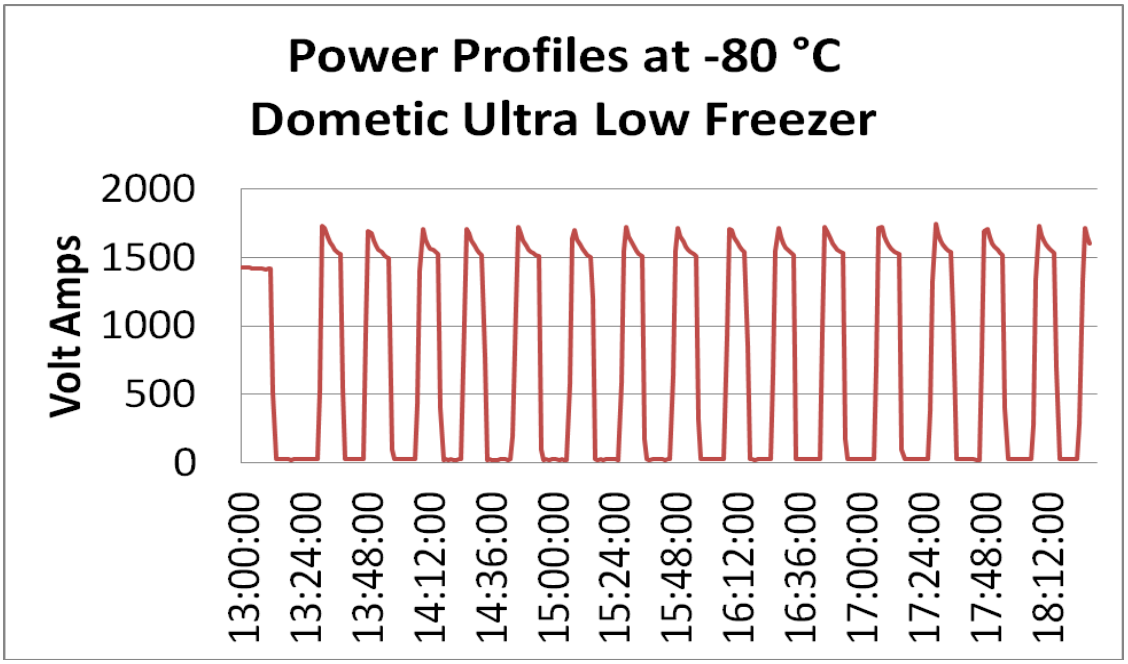
	Dometic
-60	-0.2
-70	0.3
-80	0.4
-86	0.6

Temperature measured at the installed sensor was about 0.3 degree warmer in the Dometic.

B) Thermocouple Precision measured in methanol and dry ice bath. The thermocouples were generally within 0.5 °C, though two were a degree or more from a mean of four TC's. Offsets were applied to each thermocouple's data.



C) Dometic Power profiles at -80 degrees Celsius



D) Example Dometic Data at -80 degrees Celsius logged by the Elite Pro logger.

Record Date	Record End Time	Chan 3 Avg. Volt	Chan 3 Avg. Amp	Chan 3 Avg. KW	Chan 3 Avg. PF
8/27/2011	12:35:00	204.4	7.96	1.419	0.87
8/27/2011	12:36:00	204.4	7.8	1.385	0.87
8/27/2011	12:37:00	204.3	7.65	1.353	0.87
8/27/2011	12:38:00	204.3	7.54	1.328	0.86
8/27/2011	12:39:00	204.1	7.44	1.308	0.86
8/27/2011	12:40:00	204.2	7.38	1.295	0.86
8/27/2011	12:41:00	204.1	7.34	1.285	0.86
8/27/2011	12:42:00	204	7.29	1.275	0.86
8/27/2011	12:43:00	205.6	0.49	0.077	0.77
8/27/2011	12:44:00	205.7	0.13	0.012	-0.45
8/27/2011	12:45:00	205.7	0.13	0.012	-0.45
8/27/2011	12:46:00	205.8	0.13	0.012	-0.45
8/27/2011	12:47:00	205.6	0.13	0.012	-0.44
8/27/2011	12:48:00	205.3	0.13	0.012	-0.45
8/27/2011	12:49:00	205.2	0.13	0.012	-0.45
8/27/2011	12:50:00	205.3	0.13	0.012	-0.45
8/27/2011	12:51:00	205.2	0.13	0.012	-0.44
8/27/2011	12:52:00	205.1	0.13	0.012	-0.45
8/27/2011	12:53:00	204.7	2.53	0.455	0.88
8/27/2011	12:54:00	203.9	7.52	1.352	0.88
8/27/2011	12:55:00	203.7	8.69	1.579	0.89
8/27/2011	12:56:00	203.7	8.37	1.509	0.88
8/27/2011	12:57:00	203.8	8.19	1.47	0.88
8/27/2011	12:58:00	203.8	8.04	1.439	0.88
8/27/2011	12:59:00	203.8	7.93	1.415	0.88
8/27/2011	13:00:00	203.7	7.84	1.395	0.87
8/27/2011	13:01:00	203.5	7.74	1.374	0.87
8/27/2011	13:02:00	203.6	7.67	1.36	0.87
8/27/2011	13:03:00	203.8	7.62	1.347	0.87
8/27/2011	13:04:00	204	7.56	1.335	0.87
8/27/2011	13:05:00	203.8	7.5	1.323	0.86
8/27/2011	13:06:00	203.7	7.46	1.313	0.86
8/27/2011	13:07:00	203.7	7.43	1.305	0.86
8/27/2011	13:08:00	203.6	7.39	1.298	0.86
8/27/2011	13:09:00	203.4	7.36	1.291	0.86
8/27/2011	13:10:00	203.5	7.35	1.288	0.86
8/27/2011	13:11:00	203.4	7.33	1.284	0.86
8/27/2011	13:12:00	203.4	7.32	1.282	0.86